Simplified prospective LCA models for residential PV installations based on SC-SI installed in Europe in 2050

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SIMPLIFIED PROSPECTIVE LCA MODELS FOR RESIDENTIAL PV INSTALLATIONS BASED ON SC-Si INSTALLED IN EUROPE IN 2050

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ABSTRACT

The prospective environmental impacts and electricity production capacity of residential PV systems need to be assessed for an efficient implementation planning while minimizing their environmental impacts. These impacts must be assessed using a life cycle approach, such as Life Cycle Assessment (LCA). This study is reporting the steps towards a simplified prospective model valid for residential PV systems based on single-crystalline silicon (sc-Si), installed in Europe around 2050. Prospective greenhouse gas (GHG) performance of PV installations are compared to current situation (2011-2013) accounting for technological improvements, future electricity mixes and module manufacturing origin. Recommendations to develop a simplified prospective LCA model are provided.

1. INTRODUCTION

Photovoltaic (PV) power generation capacity is projected to increase from 17 GW in 2010 to 1380 GW in 2050 in the residential sector [1]. The prospective environmental impacts and electricity production capacity of residential PV systems need to be assessed for an efficient implementation planning while minimizing their environmental impacts. These impacts must be assessed using a life cycle approach, such as Life Cycle Assessment (LCA), which is a rather complex and time-consuming method. Easy tools assessing these prospective impacts would be of high interest to help decision making. Simplified LCA models for renewable energies such as geothermal systems [2] have been recently developed. We propose in this preliminary study to investigate the necessary steps to issue such simplified prospective model. This paper focuses on residential PV systems based on single-crystalline silicon (sc-Si) to evaluate their prospective greenhouse gas (GHG) performance (in gCO_2eq/kWh). We compare the current (2011-2013) and prospective (at 2050 time horizon) GHG performances for different scenarios accounting for technological improvements, future electricity mixes and module manufacturing origin.

2. METHODS

The scope of the prospective assessment is the following:
- Technological scope: 3MWp PV installation, with modules based on si-Sc.
- Geographical scope for the installation: Europe.
- Geographical scope for the manufacturing: Europe, USA, Japan and China.
- Temporal scope: 2011-2013 period and 2050 time horizon.
- Methodological scope: The GHG performance is defined by the ratio of the global warming impact of the system (in gCO_2eq) to the electricity produced over the life cycle (in kWh). The global warming impact is assessed with the global warming potential with a time horizon of 100 years (GWP 100yr) from the IPCC 2007 [3].

The construction of a simplified prospective model would be based on two main steps: 1) the definition of a parameterized LCA model to assess the prospective GHG performance of the system 2) the reduction of this model.

For the parameterized LCA model, we first need to identify the input parameters. They correspond to parameters that are expected to evolve in the future or that induce performance variability. They are mainly technological parameters, such as module efficiency, life-time, electricity consumption for module manufacturing but also economical parameters, such as the manufacturing countries of the modules with their related background electricity mix. The values of these parameters vary according to the prospective scenarios selected: for instance in our study sc-Si module efficiency is projected to increase to reach a value between 22.9% and 27.6% by 2050. Projections of the technological parameters evolution, given in Table I, are issued from the prospective life cycle inventories realized within the PVPS Task12 [4]. For the electricity mix of the manufacturing countries, we used the different IEA scenarios [5]: the “Current Policies”, “New Policies”, and “450 scenarios”. Finally, the parameterized LCA reference model for single-crystalline silicon is built with these parameters to assess the GHG emissions and electricity production over the life-cycle following the same LCA modeling scheme as the prospective study performed on CdTe modules [6].

Table I. Parameters of the parameterized LCA model: current and prospective values (around 2050)

Parameter	Current value	Prospective value
Solar glass thickness (µm)	4 [4]	BAU:4 REAL:3 OPT:2 [4]
Wafer Thickness (µm)	190 [4]	BAU:150 REAL:120 OPT:100 [4]
Module Manufacturing origin	Germany, US, JAPAN	EU, US, JAPAN, China
Electricity mix (gCO_2eq/MJ)	values for 2013 [5]	IEA scenarios for 2035: S1, S2, S3 [1]
Site location	Europe	
Irradiation ($kWh/m^2/yr$)	Helioclim 3 database (2011-2013) [7]	
Module efficiency (%)	15.1 [4]	BAU:22.9 REAL:25.2 OPT:27.6 [4]
Life Time (yr)	30 [4]	BAU:30 REAL:35 OPT:40 [4]
Degradation (%/yr)	0.5	
Performance Ratio (%)	0.8	
Electricity quantity for module manufacturing processes (%, reduction percentage compared to current situation)	0	BAU:14 REAL:19 OPT:26 [4]

3. RESULTS

Based on prospective scenarios accounting for technological improvement, electricity mixes evolution and various si-Sc module manufacturing origin, we compare the GHG performance of 3kWp with the current situation (Fig.1) and conclude on the followings:

(1) A significant decrease of the GHG performance is highlighted (up to 60% in the most favorable case).

(2) Refinement of the parameterized model is to be undertaken by considering transport and recycling.

(3) The development of the simplified LCA model should rely on global sensitivity analysis to identify the key parameters [8] and then generate simple abaques by applying regression techniques to the identified key parameters [2].

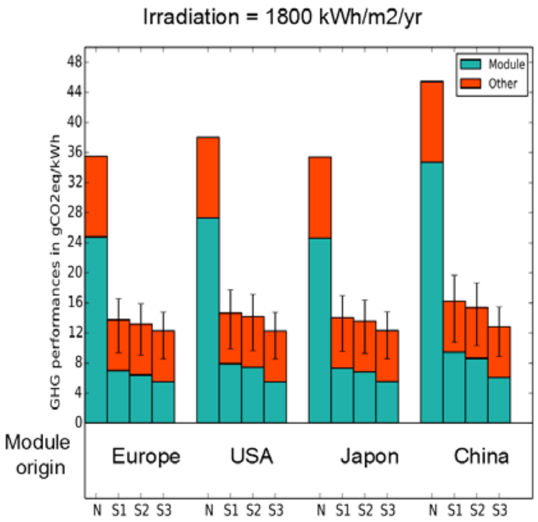

Fig.1 GHG performance for the current situation (N) and the prospective scenarios (REAL) accounting for different countries for module manufacturing. Error bars represent values obtained for the OPT and BAU scenarios. (Table I).

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